Tangle: A Tan-Based Construction Kit for 3D Modeling

New Technology

Abstract

Tangle provides students with a computer program and construction kit, inspired by an idea of 3D tangrams. Together, these tools allow students to design and build three-dimensional objects from a set of flat shapes (tans) and angle supports. Tangle serves as an introduction to computer aided modeling while also emphasizing the important role hands on building plays in developing intuitions about mathematical concepts and geometry.

Project Description

The core contribution of Tangle exists in a newly developed computer program that takes a three-dimensional object as input and decomposes it into a small set of tans and angle joins. Using a variation on the Marching Cubes algorithm, we found that most three-dimensional objects could be broken down into a form where they could be reconstructed using only three basic triangles and a small set of angle joins. The result is a physical model with a form that approximates the input model.

The current implementation of the Tangle application consists of a multi-step workflow. A user begins by importing a 3D model in STL format. Students can readily find STL-formatted files online, or with recent scanning technology, can scan their own objects. The software then decomposes the imported model into an approximation that is constructed from three basic shapes: a right triangle, an isosceles triangle, and an equilateral triangle. The user interface displays the model on one side and a list of triangle-based component shapes on the other. The list displays each type of component shape with a different color and a number indicating the quantity used. (Figure 1).

The user can modify the model by defining symmetries, adjusting specifications for the tans, and creating their own tans. Throughout the editing process, the interface provides the user visual feedback that links the action requested with the change performed.

To define symmetries in the object, the user drags a plane through the object and hits return to reflect the model on either side of the plane. By specifying a minimum edge length for the tans and adjusting the size and position of the input model the user is able to control the number of pieces needed to recreate the shape while still producing something that resembles the original model. With these ongoing adjustments, the user is able to specify parameters that make the resulting model both feasible to build and visually pleasing.

A user may also customize their model by creating new tans. The user creates new tans by combining multiple tans. For instance, joining two neighboring equilateral triangles results in the creation of a rhombus. Figure 2 shows three custom tans: a square formed by joining two isosceles triangles along the hypotenuse, a large square formed from four smaller squares, and a parallelogram created by connecting two right triangles along a matching edge. When users create their own shapes, the system dynamically locates the places those shapes fit within the model. The user may give priority to shapes by placing them higher in the list of tans.

Once the user is happy with the model, the model can be readily built. For those who have access to a laser cutter, the system is able to export a cut file of all the necessary tans and joins needed to build a model. For those who do not, it is feasible that any object can be built out of a standardized set of prebuilt tans and angles. These construction kits could be produced and shipped to students and teachers with a set of parts capable of creating a large number of objects.

In order to construct the model, a student joins neighboring tans together along an edge with an angle join piece. By nature of the algorithm, there is a small set of angles at which two tans can be joined. Each angle join has the value in degrees printed on it to aid in construction. The software also aids in the construction of the model by showing a step-by-step order for putting the model together and the angle joins to use at each edge.

In our experiments we used cardboard to build a model of Pikachu – a dog-like creature. The model contained 165 pieces and took about four hours to build (Figure 3). Less detailed models could be constructed with fewer pieces and in less time.

Tangle offers a new approach to building in 3D and presents a novel set of learning opportunities. Since many three-dimensional objects can be translated by Tangle into buildable replicas, the system offers a wide range of possible projects that can be determined by the user. The designer of the model may also determine the difficulty level of each construction in order to cater the activity for a specific learning level or to create a new challenge.

By constructing with both tans and angles, students have a more advanced and directed approach in construction as opposed to similar toys such as Magnatiles. While the concept of building with flat shapes may be familiar, with Tangles students also begin to develop concrete notions of how shapes come together in order to construct meaningful structures. Overall, Tangle presents an opportunity to learn in a fun and playful way.

Figures:

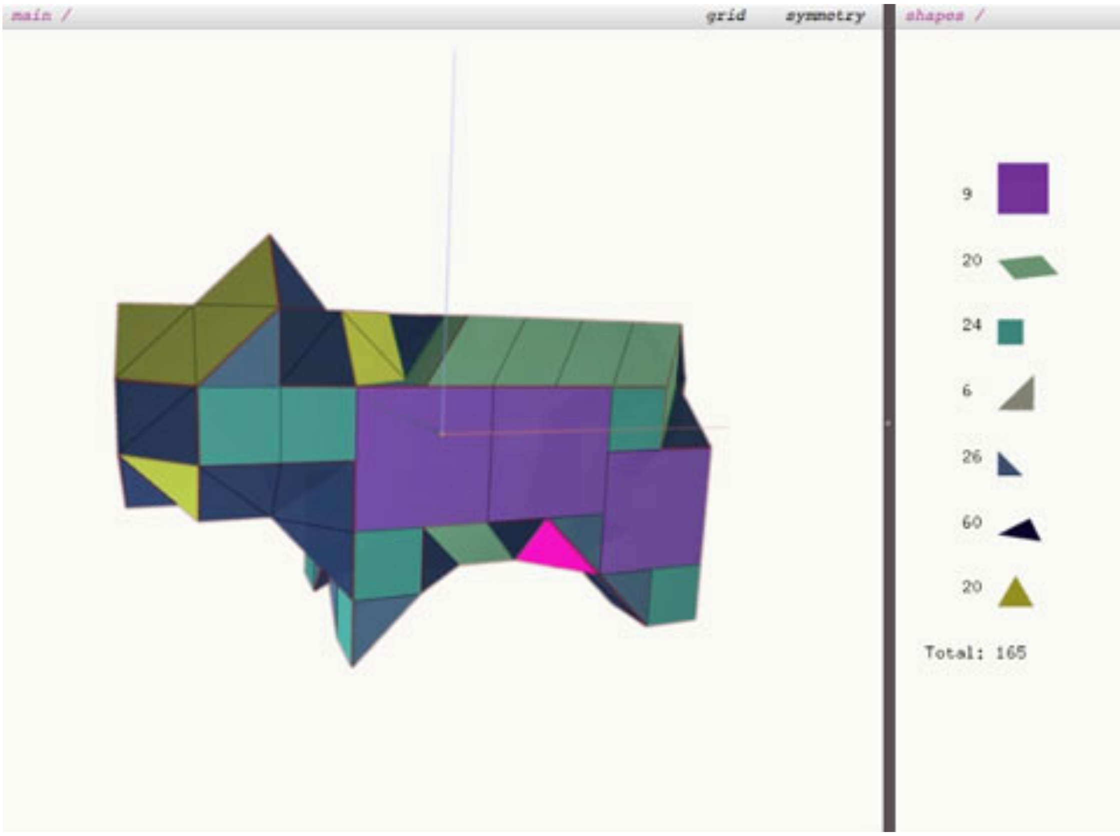

Figure 1: A user may begin by designing their model on the computer. This particular model is being created out of the three shapes triangles by the algorithm and three user defined shapes created by joining the triangles together. The physical model created from this simulation is shown in Figure 3

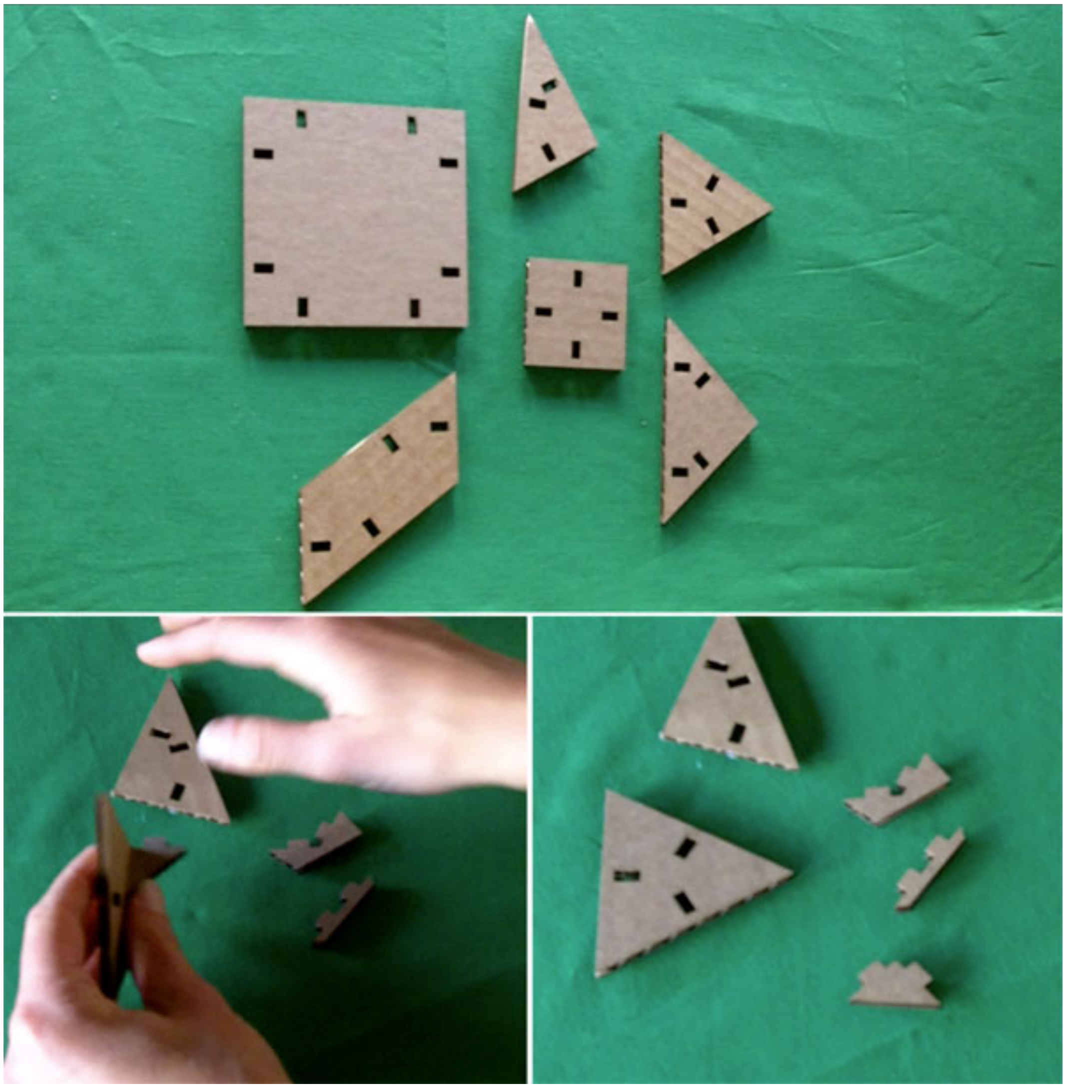

Figure 2: A detail of tans and able joins. Two tans are joined together by an angle join.

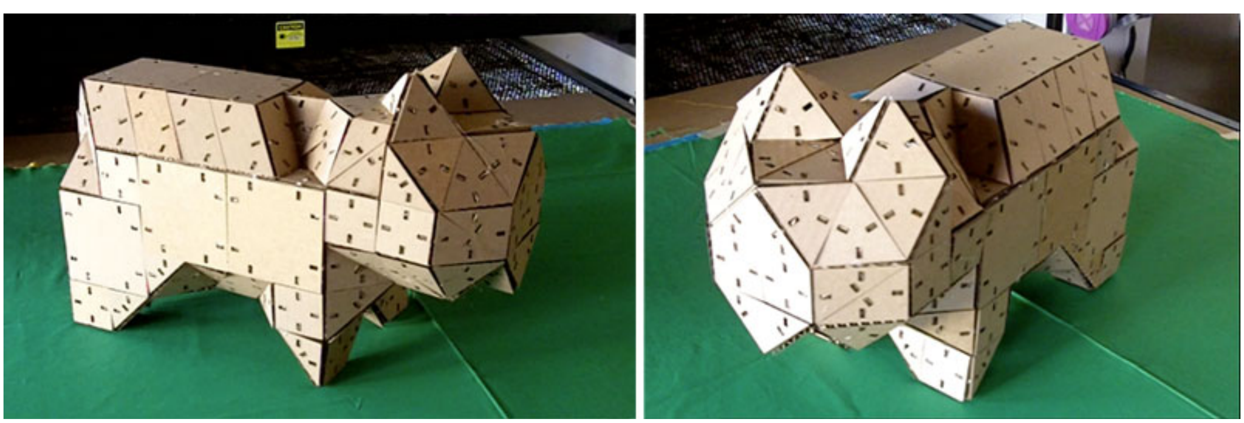

Figure 3: A model of Pikachu built using tangle with consisting of 165 cardboard tans and angle supports.